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Relationships between emotion regulation strategies and executive functions in adolescence: Exploring the effects of discrete emotions and age

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Abstract

Introduction: Emotion regulation (ER) develops during adolescence and contributes to psychosocial adjustment. Individual differences in the development of ER strategies may be related to cognitive processes responsible for managing goal-directed behaviors, namely executive functions (EFs). This study examined (1) examined how difficulties in specific EFs (i.e., inhibition, flexibility and working memory) predict the use of ER strategies (i.e., reappraisal, distraction, expressive suppression, rumination, support-seeking) in an emotion-specific approach and (2) investigated these links across three different age groups (corresponding to early, middle and late adolescence), considering the nonlinear evolution of the relationships between EF and ER strategies during adolescence.

Methods: The sample was composed of 1076 adolescents aged from 12 to 19 years old who completed questionnaires on EF difficulties (i.e., inhibition, flexibility, and working memory) and ER strategies (i.e., distraction, reappraisal, expressive suppression, social support-seeking, and rumination).

Results: Results showed various complex relationships between EFs and ER. Flexibility issues were related to rumination at all ages, while inhibition and flexibility difficulties were negatively linked to reappraisal in mid- to late adolescence. Many relationships were emotion- and age-dependent.

Conclusions: These findings support the link between cognitive and emotional regulatory processes. Its complex evolution during adolescence opens a new avenue for future research.

KEYWORDS

adolescence, discrete emotions, emotion regulation strategies, executive functions

1 | INTRODUCTION

Adolescence is characterized by physiological, cognitive, emotional and social changes, as well as the emergence of new emotional situations (e.g., development of romantic relationships, Silk et al., 2003). Dealing with such challenges requires emotion regulation (ER), defined as the "processes responsible for monitoring, evaluating and modifying emotional reactions, especially their intensive and temporal features, to accomplish one's goals" (Thompson, 1994, pp. 27–28). ER strategies are a critical component of these processes as they refer to the actions or attempts of individuals to achieve regulation (Gross, 2015). In adulthood, the use of strategies depends on contextual factors (e.g., Aldao, 2013; Hartmann et al., 2024), especially the discrete emotions one feels in a particular situation (e.g., anger or sadness). Although their use is considered stable across emotional situations, most studies on ER in adolescence have examined only a few strategies. It is therefore essential to conduct studies that examine the role of discrete emotions in adolescents' ER (De France & Hollenstein, 2022; Fombouchet, Pineau, et al., 2023).

The range of strategies used across situations, called the "ER repertoire," increases during adolescence. Teenagers use several strategies such as distraction (e.g., focusing attention away from an emotional situation), reappraisal (e.g., modifying the perception of the situation), rumination (e.g., focusing on the negative aspects and emotions of the situation), support-seeking (e.g., asking for help to regulate emotions), and expressive suppression (e.g., modulating the expression of emotion). They are generally considered as effective (i.e., reappraisal, distraction), maladaptive (i.e., expressive suppression, rumination) or in between (i.e., support-seeking, Lennarz et al., 2019). In a given situation, adolescents prefer to use one strategy rather than another, which demonstrates interindividual differences in ER (e.g., Lougheed & Hollenstein, 2012; Sheppes et al., 2014). However, the choice and effectiveness of ER strategies are driven by the contextual cues and discrete emotions associated with each emotional situation (De France & Hollenstein, 2022). Negative emotions of sadness, fear or anger may activate different goals of regulation, leading to the use of different ER strategies. Reappraisal is more likely to be used in situations of anxiety, while sadness or anger are more likely to be managed by using distraction and expressive suppression (De France & Hollenstein, 2022). Importantly, emotion-related differences in ER strategies evolve with age. The use of expressive suppression increases from early to late adolescence, especially to deal with fear more often than with sadness or anger (Zimmermann & Iwanski, 2014). Given this variability and the emotion-specific evolution in the use of ER strategies in adolescence, the processes related to these changes need to be investigated.

Individual differences in ER may be related to executive functions (EFs), cognitive processes that enable individuals to control their thoughts and actions to pursue goal-directed behaviors (Pruessner et al., 2020). As EFs continue to develop during adolescence (e.g., Theodoraki et al., 2020), the present study aimed to investigate (1) whether EFs predict the use of ER strategies in situations inducing discrete emotions (i.e., anger, sadness and fear) and (2) how the relationships between EFs and ER strategies evolve during adolescence.

The core EFs (Miyake & Friedman, 2012) are inhibition (i.e., suppression of task-irrelevant stimuli), flexibility (i.e., switching attention from one task to another) and working memory (i.e., transiently maintaining and manipulating task-relevant information). In adolescence, they account for individual performance in EFs tasks (e.g., Theodoraki et al., 2020; Xu et al., 2013). They follow specific developmental trajectories as the prefrontal cortex matures up to the mid-20s (Theodoraki et al., 2020). While working memory stabilizes around 15 years old, inhibition and flexibility develop until early adulthood (Ferguson et al., 2021; Theodoraki et al., 2020). The protracted development of these EFs may contribute to increase the use of complex ER strategies adapted to each emotional situation (Schweizer et al., 2020).

Adolescents experience heightened emotionality and a greater sensitivity to social and contextual influences (Guyer et al., 2016). This overactivation of emotions and the ongoing maturation of neurological structures responsible for regulatory processes lead to a greater reliance on maladaptive strategies (e.g., rumination) than on strategies considered as adaptive (e.g., reappraisal) and cognitively costly (Cracco et al., 2017; Zimmermann & Iwanski, 2014). However, this phenomenon decreases in late adolescence: EFs are more mature, thereby enabling a better integration of contextual information, a greater identification and maintenance of regulatory goals, and more appropriate decision-making (Berthelsen et al., 2017). These abilities are crucial for the choice and successful use of relevant ER strategies in each situation (Gross, 2015), and may be particularly critical in the context of a specific emotion (e.g., sadness, fear or anger). Importantly, EFs deficits are associated with difficulties in ER processes (e.g., Dickson & Ciesla, 2018), the latter being identified as a risk factor for the emergence of emotional and behavioral problems (e.g., Aldao et al., 2010). Hence, examining the differential impact of EFs on ER strategies in an emotion-specific approach has implications for practice. For instance, it may help to design psychological interventions (e.g., prevention or intervention programs) targeting internalizing (e.g., anxiety, depression) and externalizing disorders (e.g., conduct disorder).

Few studies to date have investigated the links between specific EFs and ER strategies in adolescence. Using self-report measures, Dickson and Ciesla (2018) found that difficulties in inhibition and flexibility predicted the use of rumination in late adolescence (i.e., 16–18 years old). Although Lantrip et al. (2016) did not evidence a relationship between these two EFs and expressive suppression or reappraisal using a similar method in a wider age range (i.e., 12–18 years old), they found links between difficulties in working memory and expressive suppression. However, these two studies suffer from limitations. First, only a few ER strategies were considered: either rumination (Dickson & Ciesla, 2018), or reappraisal and expressive suppression (Lantrip et al., 2016). Second, they were measured in a general context, without considering the putative effects of discrete emotions. Third, these studies do not account for age differences in the relationships between EFs and ER strategies. Finally, both studies had small sample sizes (<100) and neither provided information on the evolution of the relationships between EFs and ER strategies in adolescence.

1.1 | Aims of study

The present study aimed to bolster knowledge about how EFs may underlie the evolution of ER during adolescence. To address gaps in the existing literature, this study had two main goals: (1) we examined how difficulties in specific EFs (i.e., inhibition, flexibility, working memory) predict the use of ER strategies (i.e., reappraisal, distraction, expressive suppression,

rumination, support-seeking) in an emotion-specific approach and (2) we investigated these links across three different age groups (corresponding to early, middle and late adolescence), considering the nonlinear evolution of the relationships between EF and ER strategies during adolescence (e.g., Cracco et al., 2017). First, we expected to find relationships between EFs and ER in every emotional situation: we hypothesized that difficulties in EFs predict a lesser use of reappraisal and distraction, and a greater use of rumination and expressive suppression (Dickson & Ciesla, 2018; Lantrip et al., 2016). However, these links were expected to be stronger in anger and sadness than in fear situations, owing to the differences between discrete emotions in individual control and perceived certainty (e.g., Habib et al., 2015). Second, we posited that while the relationships are stable between EF difficulties and maladaptive ER strategies such as rumination from early to late adolescence (e.g., Joormann & Vanderlind, 2014), they change in relation to age between EF difficulties and adaptive ER strategies. Since the use of ER strategies becomes more complex and adapted as EFs develop (e.g., Pruessner et al., 2020; Theodoraki et al., 2020; Zimmermann & Iwanski, 2014), we expected a stronger negative relationship between EF difficulties and reappraisal in late than in early adolescence.

2 | METHOD

2.1 | Participants

The sample was composed of 1076 middle and high schoolers (M_{age} = 14.5; SD_{age} = 1.55, $range_{age}$ = 12–19 years, 547 males, 526 females, three participants did not report their gender), divided into three age groups, corresponding to early (12–14 years old, N = 453), middle (14–16 years old, N = 382), and late adolescence (16–19 years old, N = 241). All participants were recruited in six French middle and high schools (71.7% middle schoolers).

2.2 | Measures and procedure

ER was assessed using the Contextualized Emotion Regulation Survey for Adolescents (CERSA, Fombouchet Lannegrand, et al., 2023), a French self-report scale that evaluates five ER strategies (reappraisal, distraction, expressive suppression, support-seeking, and rumination) in three negative situations designed to elicit specific emotions (i.e., sadness, fear, and anger). The emotional situations assess ER in an interpersonal context at school. In every situation, the strategies were measured with four items each on a seven-point Likert-type scale (from 1 "Not at all like that" to 7 "Totally like that"). Internal consistency of strategies was good across situations, with McDonald's ω ranging from 0.827 to 0.916 for sadness, from 0.830 to 0.892 for fear, and from 0.831 to 0.908 for anger.

EFs were assessed using the French version of the Behavioral Rating Inventory of Executive Function (BRIEF2-SR, Hogrefe), a self-report rating scale for children and adolescents aged 11–18 years old. Based on the tripartite model of EFs, we selected items for inhibition, flexibility and working memory. These items were rated on a three-point scale (never, sometimes, often), with higher scores reflecting greater difficulty with EF. The French version of the BRIEF2-SR is still unpublished but international research has highlighted its good psychometric properties, including internal consistency and test–retest reliability (Hendrickson & McCrimmon, 2019). Internal consistency of EFs was acceptable, with McDonald's ω ranging from 0.700 to 0.731. The participants filled out both the CERSA and the BRIEF2-SR in the classroom. Results regarding the construct validity of the questionnaires are provided in Supporting Information Materials.

2.3 | Data analysis

All analyses were performed using R 4.0.3. The proportion of missing data for items of both questionnaires was 0.453%. To deal with the missing data, multiple imputations were run using the missMDA package, which has the advantage of having little to no weight in factor and further analyses (Josse & Husson, 2016). Confirmatory factor analyses (CFA) with the MLM estimator were performed using the lavaan package (Rosseel, 2012) to evaluate the internal validity of the CERSA and using the WLSMV estimator for the three dimensions of the BRIEF2-SR (see Supporting Information Materials).

Based on these measurement models, structural equation models were performed with the MLM estimator using semTools and lavaan packages (Jorgensen et al., 2021; Rosseel, 2012), to assess whether the latent factors of EFs predicted the latent factors of ER strategies in each situation of the CERSA. Similarly, multigroup comparisons with three age groups (i.e., 12–14, 14–16, and 16–19 years old) were conducted to determine whether the relationships between the latent factors of EFs and ER strategies changed with age. Soper's (2024) calculator was used to determine the sample size required for SEM with a statistical power of 80% and weak effect sizes (i.e., 0.15). This resulted in an estimation of 818 participants, lower than data collection.

3 | RESULTS

Descriptive statistics on mean levels for dimensions of CERSA and BRIEF2-SR are reported in Table 1.

3.1 | Predictions of ER strategies by EF difficulties

In the sadness situation, the tested model provided a good fit: $\chi^2(674) = 1482$, $p < .001$, $\chi^2/df = 2.199$, CFI = 0.938, RMSEA = 0.035 [0.033–0.037], SRMR = 0.039. Overall effects were significant for rumination, $R^2 = 0.150$, followed by reappraisal, $R^2 = 0.034$, expressive suppression, $R^2 = 0.026$, and social support-seeking $R^2 = 0.023$. Distraction, $R^2 = 0.005$ was not related to any statistical effect. Difficulties in inhibition negatively predicted reappraisal, $b = -0.822$, 95% confidence interval [CI] [−1.410, −0.234], $z = 2.740$, $p = .006$, $\beta = .164$, and positively predicted social support-seeking, $b = 0.582$, 95% CI [0.039, 1.126], $z = 2.102$, $p = .036$, $\beta = .127$. Difficulties in flexibility positively predicted social support-seeking, $b = 0.459$, 95% CI [0.068, 0.850], $z = 2.302$, $p = .021$, $\beta = .112$, and rumination, $b = 2.012$, 95% CI [1.430, 2.594], $z = 6.778$, $p < .001$, $\beta = .358$. Difficulties in working memory negatively predicted social support-seeking, $b = -0.574$, 95% CI [−1.024, −0.124], $z = 2.499$, $p = .012$, $\beta = .161$.

In the fear situation, the model showed a good fit: $\chi^2(674) = 1493$, $p < .001$, $\chi^2/df = 2.215$, CFI = 0.933, RMSEA = 0.035 [0.033–0.038], SRMR = 0.038. Size effects were larger for rumination, $R^2 = 0.102$, followed by reappraisal, $R^2 = 0.027$, social support-seeking $R^2 = 0.020$, and expressive suppression, $R^2 = 0.015$. Distraction was the only strategy that did not provide significant results, $R^2 = 0.004$. Difficulties in inhibition negatively predicted reappraisal, $b = -0.916$, 95% CI [−1.590, −0.241], $z = 2.661$, $p = .008$, $\beta = .162$. Difficulties in flexibility positively predicted social support-seeking, $b = 0.731$, 95% CI [0.275, 1.187], $z = 3.143$, $p = .002$, $\beta = .156$, and rumination, $b = 1.782$, 95% CI [1.239, 2.326], $z = 6.425$, $p < .001$, $\beta = .336$.

In the anger situation, the model yielded a good fit: $\chi^2(674) = 1506$, $p < .001$, $\chi^2/df = 2.234$, CFI = 0.934, RMSEA = 0.036 [0.033–0.038], SRMR = 0.040. The proportion of explained variance was larger for rumination, $R^2 = 0.148$, followed by reappraisal, $R^2 = 0.032$, social support-seeking $R^2 = 0.014$, expressive suppression, $R^2 = 0.011$, and distraction, $R^2 = 0.007$. Difficulties in inhibition negatively predicted reappraisal, $b = -0.835$, 95% CI [−1.502, −0.168], $z = 2.453$, $p = .014$, $\beta = .145$. Difficulties in flexibility positively predicted support-seeking, $b = 0.711$, 95% CI [0.198, 1.224], $z = 2.716$, $p = .007$, $\beta = .135$, and rumination, $b = 2.091$, 95% CI [1.509, 2.674], $z = 7.034$, $p < .001$, $\beta = .359$. Difficulties in working memory positively predicted expressive suppression, $b = 0.701$, 95% CI [0.078, 1.324], $z = 2.205$, $p = .027$, $\beta = .142$.

3.2 | Developmental changes in EFs and ER relationships

In the sadness situation, the multigroup model based on the age of adolescents provided a good fit: $\chi^2(2022) = 2911$, $p < .001$, $\chi^2/df = 1.440$, CFI = 0.927, RMSEA = 0.036 [0.033–0.039], SRMR = 0.052. In early adolescence, the strategy of rumination

TABLE 1 Descriptive statistics for ER strategies and EF difficulties according to age groups (i.e., 12–14, 14–16, and 16–19 years old).

	Sadness situation			Fear situation			Anger situation		
	12–14 y.o.	14–16 y.o.	16–19 y.o.	12–14 y.o.	14–16 y.o.	16–19 y.o.	12–14 y.o.	14–16 y.o.	16–19 y.o.
Strategies	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)
Distraction	3.90 (1.77)	3.84 (1.82)	3.89 (1.85)	3.56 (1.93)	3.44 (1.92)	3.16 (1.90)	3.48 (2.00)	3.43 (1.93)	3.37 (1.91)
Reappraisal	3.42 (1.66)	3.36 (1.68)	4.01 (1.66)	3.29 (1.75)	3.10 (1.76)	3.68 (1.73)	2.85 (1.61)	2.69 (1.60)	2.93 (1.61)
Expressive suppression	3.97 (1.98)	4.07 (2.09)	4.36 (2.06)	3.79 (1.86)	3.65 (1.91)	3.94 (1.89)	3.84 (1.90)	3.70 (1.89)	4.16 (1.82)
Support-seeking	3.63 (1.78)	3.37 (1.76)	3.26 (1.72)	3.61 (1.86)	3.55 (1.82)	3.73 (1.79)	3.73 (1.86)	3.56 (1.83)	3.68 (1.83)
Rumination	3.71 (1.84)	3.44 (1.74)	3.22 (1.79)	3.16 (1.70)	2.98 (1.67)	3.31 (1.80)	3.97 (1.88)	4.12 (1.73)	4.14 (1.86)
	12–14 y.o.			14–16 y.o.			16–19 y.o.		
EFs	M (SD)			M (SD)			M (SD)		
Inhibition	1.90 (0.45)			1.86 (0.45)			1.73 (0.43)		
Flexibility	1.72 (0.43)			1.69 (0.41)			1.66 (0.40)		
Working memory	1.81 (0.41)			1.90 (0.44)			1.80 (0.42)		

Abbreviations: CI, confidence interval; EF, executive functions; ER, emotion regulation.

yielded the strongest effects, $R^2 = 0.244$, followed by social support-seeking, $R^2 = 0.059$, and expressive suppression, $R^2 = 0.039$. Reappraisal, $R^2 = 0.021$ and distraction, $R^2 = 0.004$ were not related to statistical effects. In middle adolescence, predictions were weaker yet significant for the strategy of rumination, $R^2 = 0.122$, and social support-seeking $R^2 = 0.042$. The other three strategies did not lead to significant results with reappraisal, $R^2 = 0.028$, expressive suppression, $R^2 = 0.019$, and distraction, $R^2 = 0.013$. In late adolescence, reappraisal, $R^2 = 0.091$ was related to significant results, as was rumination, $R^2 = 0.082$, and expressive suppression, $R^2 = 0.055$. Support-seeking, $R^2 = 0.026$ and distraction, $R^2 = 0.017$ were not related to statistical effects. Specific effects are reported in Table 2.

In the fear situation, the multigroup model tested showed a good fit to the data: $\chi^2(2022) = 2974$, $p < .001$, $\chi^2/df = 1.471$, CFI = 0.918, RMSEA = 0.038 [0.035–0.041], SRMR = 0.051. In early adolescence, explained variance was the largest for rumination, $R^2 = 0.114$, which was the only strategy related to EF difficulties. No other strategies were related to significant results, with expressive suppression, $R^2 = 0.044$, reappraisal $R^2 = 0.031$, social support-seeking, $R^2 = 0.010$, and distraction, $R^2 = 0.005$. In middle adolescence, size effects were larger for rumination, $R^2 = 0.092$, followed by social support-seeking, $R^2 = 0.040$. Reappraisal, $R^2 = 0.023$, distraction, $R^2 = 0.019$, and expressive suppression, $R^2 = 0.008$, did not yield significant results. In late adolescence, EF difficulties were related to rumination, $R^2 = 0.116$, and reappraisal, $R^2 = 0.057$, but not to social support-seeking, $R^2 = 0.035$, expressive suppression, $R^2 = 0.033$, and distraction, $R^2 = 0.014$. Specific effects are reported in Table 3. Regarding sadness, difficulties in flexibility predicted the use of rumination and remained stable across all age groups.

In the anger situation, the multigroup model tested fitted the data well: $\chi^2(2022) = 2980$, $p < .001$, $\chi^2/df = 1.474$, CFI = 0.919, RMSEA = 0.038 [0.035–0.041], SRMR = 0.051. In early adolescence, size effects were larger for rumination, $R^2 = 0.154$, followed by expressive suppression, $R^2 = 0.027$, and social support-seeking, $R^2 = 0.026$. Distraction, $R^2 = 0.023$, and reappraisal, $R^2 = 0.011$, were not related to EF difficulties. In middle adolescence, overall predictions were stronger for rumination, $R^2 = 0.137$, followed by reappraisal, $R^2 = 0.054$, and social support-seeking, $R^2 = 0.033$. Distraction, $R^2 = 0.018$,

TABLE 2 Significant and marginal effects for multigroup structural equations models conducted in sadness situation, with latent factors of EF difficulties predicting latent factors of ER strategies.

1st age group [12–14]				
	b [95% CI]	*Z*	*p*	*β*
Flexibility				
Social support-seeking	1.039 [0.320, 1.758]	2.833	.005	.280
Rumination	2.601 [1.627, 3.589]	5.210	<.001	.537
Working memory				
Social support-seeking	−1.521 [−2.781, −0.260]	2.365	.018	.364
2nd age group [14–16]				
Inhibition				
Social support-seeking	1.020 [0.225, 1.815]	2.515	.012	.274
Flexibility				
Rumination	1.787 [0.809, 2.766]	3.581	<.001	.304
Working memory				
Social support-seeking	−0.635 [−1.303, 0.034]	1.861	.063	.205
3rd age group [16–19]				
Inhibition				
Reappraisal	−1.333 [−2.199, −0.467]	3.018	.003	.304
Expressive suppression	1.423 [0.227, 2.619]	2.333	.020	.218
Flexibility				
Rumination	1.756 [0.260, 3.251]	2.301	.021	.208
Working memory				
Rumination	0.837 [−0.057, 1.730]	1.835	.067	.165

Abbreviations: CI, confidence interval; EF, executive functions; ER, emotion regulation.

TABLE 3 Significant and marginal effects for multigroup structural equations models conducted in fear situation, with latent factors of EF difficulties predicting latent factors of ER strategies.

1st age group [12–14]				
	b [95% CI]	*z*	*p*	*β*
Flexibility				
Rumination	1.508 [0.629, 2.386]	3.363	<.001	.326
2nd age group [14–16]				
Flexibility				
Social support-seeking	0.771 [−0.001, 1.544]	1.957	.050	.153
Rumination	1.714 [0.807, 2.621]	3.703	<.001	.333
Working memory				
Social support-seeking	−0.957 [−1.781, −0.133]	2.275	.023	.242
3rd age group [16–19]				
Inhibition				
Reappraisal	−1.124 [−2.024, −0.225]	2.449	.014	.228
Rumination	1.087 [−0.034, 2.209]	1.901	.057	.179
Flexibility				
Social support-seeking	1.270 [0.121, 2.418]	2.167	.030	.195
Rumination	2.234 [0.783, 3.685]	3.018	.003	.268

Abbreviations: CI, confidence interval; EF, executive functions; ER, emotion regulation.

and expressive suppression, $R^2 = 0.005$, did not yield significant results. Finally, in late adolescence, the strategy of rumination was explained the most by EF difficulties, $R^2 = 0.162$, followed by reappraisal, $R^2 = 0.112$. Other strategies did not provide significant results with expressive suppression, $R^2 = 0.025$, distraction, $R^2 = 0.023$, and support-seeking, $R^2 = 0.020$. Specific effects are reported in Table 4. As for sadness and fear, flexibility difficulties positively predicted rumination in all age groups and several predictions were present only at specific ages, with inhibition negatively predicting reappraisal in middle and late adolescence.

4 | DISCUSSION

This study had two main goals. First, we analyzed the relationships between inhibition, flexibility and working memory difficulties with multiple ER strategies in situations that induced specific emotions of sadness, fear and anger. Second, we observed how these relationships evolve from early to late adolescence. Overall, our results highlight a complex dynamic between EF difficulties and ER strategies during adolescence, with both stability and variability depending on emotional situations and age.

4.1 | Specific links between EF difficulties and ER strategies across emotional situations

We found systematic relationships between specific EFs and ER strategies in all emotional situations with noticeable variations in effect sizes. First, the strongest effect concerned difficulties in flexibility, the later predicting rumination in line with Dickson and Cielsa's results (2018). As adolescents demonstrate a heightened sensitivity to contextual and emotional cues (e.g., Guyer et al., 2016), difficulties to disengage attention from negative emotional stimuli may arise, thereby inducing rumination (Koster et al., 2011; Nolen-Hoeksema et al., 2008). Second, difficulties in inhibition were negatively related to reappraisal. This relationship was previously evidenced in adults (e.g., Cohen et al., 2014) and may be interpreted in adolescents as a need to inhibit their first interpretation of a situation to reconsider its meaning (Gross, 2015). Third, difficulties in working memory were linked to expressive suppression, in line with Lantrip et al. (2016). Since a lower working memory capacity is generally associated with limited cognitive resources, it may hinder the use of strategies that are more suited to reduce negative emotions (e.g., distraction, reappraisal), therefore resulting in a narrower ER repertoire. However, these strategies are also more complex since individuals have to shift their

TABLE 4 Significant and marginal effects for multigroup structural equations models conducted in anger situation with latent factors of EFs difficulties predicting latent factors of ER strategies.

1st age group [12–14]				
	b [95% CI]	*z*	*p*	*β*
Flexibility				
Social support-seeking	0.911 [0.012, 1.810]	2.833	.047	.189
Rumination	2.097 [1.099, 3.094]	4.119	<.001	.400
Working memory				
Expressive suppression	1.547 [−0.127, 3.216]	1.811	.070	.268
2nd age group [14–16]				
Inhibition				
Reappraisal	−1.172 [−2.187, −0.158]	2.265	.024	.250
Rumination	1.218 [0.099, 2.338]	2.133	.033	.227
Flexibility				
Rumination	1.644 [0.771, 2.517]	3.690	<.001	.293
Working memory				
Social support-seeking	−0.938 [−1.835, −0.041]	2.050	.040	.222
3rd age group [16–19]				
Inhibition				
Reappraisal	−1.404 [−2.310, −0.498]	3.036	.002	.271
Flexibility				
Reappraisal	−0.995 [−2.121, 0.131]	1.731	.083	.143
Rumination	3.143 [1.495, 4.790]	3.734	<.001	.369

Abbreviations: CI, confidence interval; EF, executive functions; ER, emotion regulation.

attention from their first perception of a situation towards new representations or contextual aspects (e.g., Schmeichel & Tang, 2015). Finally, there were few to no links between EF difficulties and distraction. We posit that this strategy is less related to EF difficulties as it requires less deliberate control than others, such as reappraisal (Scheibe et al., 2015). Distraction may also be interpreted as a form of avoidance by some participants, thus masking its relationships with EF difficulties. This hypothesis needs to be investigated in future studies.

4.2 | Links between EF difficulties and ER strategies depending on emotional situations

Relationships between difficulties in EFs and specific ER strategies varied according to the emotional situation. Social support-seeking was predicted by difficulties in the three EFs in the sadness situation, whereas it was predicted only by difficulties in flexibility in the fear and anger situations. In the sadness situation, adolescents may fail to use autonomous regulation. It may also indicate that the support they receive has more to do with corumination than assistance in regulating emotions (Dixon-Gordon et al., 2015). Furthermore, it was only within the anger situation that working memory difficulties predicted the use of expressive suppression. This result indicates that EFs difficulties may prevent adolescents from using other strategies that down-regulate anger such as distraction or reappraisal.

Building upon previous studies that have predominantly focused on global measures of EF and ER (e.g., Lantrip et al., 2016), our findings highlight the importance of considering emotion-specific effects. For instance, while EF deficits may pose challenges for ER across negative emotions, our results suggest that the relationships vary depending on the specific emotional content involved. In adolescence, social contexts are more salient and elicit specific emotions, which may challenge the use of ER strategies (Crone & Dahl, 2012). EFs efficiency may facilitate flexible responding among emotional social contexts (Aldao et al., 2015). Thus, by exploring these relationships, our study suggests that individual differences in EFs are related to context sensitivity, a crucial component of ER flexibility (Bonanno & Burton, 2013).

4.3 | Age-related changes in relationships between EF difficulties and ER strategies

The relationships between EFs and ER strategies were stable or variable, depending on age, emotional situation and strategy considered. Regarding stability, rumination was predicted by difficulties in flexibility in all age groups and in all emotional situations. This is particularly interesting as flexibility follows the most protracted development, relying highly on the two other EFs (Theodoraki et al., 2020). It may help reduce rumination, both by decreasing the focus on negative emotions and allowing the use of other strategies from the ER repertoire of adolescents. Previous research has shown that repetitive rumination decreases flexibility abilities as negative thinking places additional demands on limited executive resources (e.g., Joormann & Vanderlind, 2014). Since rumination is associated with depression, anxiety and self-harm (e.g., Nolen-Hoeksema et al., 2008), intervention programs focusing on emerging psychopathologies characterized by ruminative thoughts (e.g., depression) may benefit from targeting the improvement of flexibility abilities.

Most relationships between EFs and ER strategies were significant only in specific age groups. First, we observed a specificity in early adolescence. While flexibility difficulties predicted rumination in the fear situation, they predicted social support-seeking in the sadness and anger situations. Research has evidenced that sadness and anger involve a higher sense of individual and situational control than fear (e.g., Lerner et al., 2015).

Second, inhibition difficulties were related to reappraisal in mid-adolescence only in the anger situation. This was also evidenced in late adolescence in all emotional situations. These age-related differences may be explained by the fact that reappraisal becomes efficient during mid-to-late adolescence (e.g., Silvers & Guassi Moreira, 2019). Overall, our results suggest that the development of EFs plays a role in the use of reappraisal during adolescence.

4.4 | Limitations and perspectives

These findings offer new insights into the interplay between ER, EFs and emotional situations in adolescents. However, this study has limitations. First, the use of a three-point Likert-type scale for the assessment of EFs may have narrowed the variability of BRIEF scores, resulting in weak effect sizes. Evaluating the validity of the BRIEF2-SR on a five-point scale (i.e., adding "rarely" and "almost always/always" as possibilities) would result in more diverse responses to identify whether ER strategies are more related to EFs efficiency or difficulties. Second, the BRIEF2-SR is a questionnaire that assesses adolescents' representations of their own difficulties in EFs. Using both performance-based and self-report measures to evaluate the associations between ER strategies and EFs would help to explain the discrepancies found in the literature and to further our understanding of these links. Third, the study focused on the predictions of ER by EFs in adolescence. However, the use of costly ER strategies may also promote the development of EFs in complex emotional situations. Longitudinal designs should therefore be conducted to investigate the directionality of the relationships between EFs and ER in adolescence.

5 | CONCLUSION

This study highlights strong relationships between EFs and ER processes during adolescence when considering the influence of discrete emotions. The results show that EF difficulties may either hinder or bolster the use of ER strategies in adolescence. These strategies were linked to specific EFs, with both stability and variability depending on the emotional situation and developmental specificities that were highlighted. Stable links were identified between EFs and ER strategies throughout adolescence, especially between flexibility and rumination. However, they were significant only in specific age groups, with inhibition difficulties negatively predicting reappraisal in mid- and late adolescence. Considering the key role played by functional ER in coping with the changes that occur during adolescence, further developmental research is needed to develop our knowledge of regulatory processes in various emotional contexts.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Data and Rcode supporting the findings of this study are available on request from the corresponding author. The data are not publicly available due to the General Data Protection Regulation (GDPR) and the Commission Nationale de l'Informatique et des Libertés (CNIL). The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

ETHICS STATEMENT

Ethical approval for this study was obtained from the Comité local d'éthique of the Laboratory of Psychology, Bordeaux, France. This research was conducted in compliance with the Declaration of Helsinki, GDPR, CNIL and French Code de Déontologie des Psychologues. All participants and parents provided informed consent before the study.

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